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The Impact of Physical Distance on COVID-19 Transmission: A Comprehensive Review of Evidence and Implications

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ABSTRACT

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a member of the Corona-viridian family, is responsible for the emergence of the 2019 novel coronavirus disease (COVID-19), which has developed into a worldwide pandemic since its initial detection in Wuhan, Hubei province of China, in early December 2019. The objective of this study was to investigate the impact of physical distancing measures on the transmission of COVID-19. A scoping review was conducted, with a focus on English-language literature available on Pub Med and Web of Science up to May 2022. The findings of this study indicate a statistically significant correlation between physical distance and the transmission of COVID-19. Nevertheless, it should be noted that COVID-19 primarily spreads through contact routes and respiratory droplets, and many aspects of its transmissibility are still not fully understood. As such, the topic of airborne transmission of COVID-19 remains a subject of debate and controversy.

1. Introduction

SARS-CoV-2, also known as the Coronavirus or Acute Respiratory Syndrome Coronavirus 2, is a pathogen capable of impacting the human respiratory system. The corresponding viral illness is referred to as Corona Virus Disease 2019 (COVID-19) [1, 2]. The Coronavirus plays a significant role in the manifestation of mild respiratory disorders, severe lung infections, and even fatalities [3]. It was initially identified in late 2019 in Wuhan, China [4]. Its rapid spread among the human population is facilitated through direct contact with infected individuals or contact with contaminated objects, leading to infection within a relatively short period [5]. Epidemiological studies have consistently demonstrated the strong recommendation of physical distancing by national and international institutions as a primary measure to reduce viral transmission [6]. Therefore, it is crucial to refrain from frequenting crowded places such as markets, places of worship, entertainment venues, and educational facilities [7]. Every possible effort must be undertaken to prevent the transmission of the virus to others [8]. Physical distancing is widely acknowledged as one of the most effective strategies for preventing the spread of Covid-19 [9]. The precise mechanisms underlying the

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potential for small droplets or particle nuclei to disperse over extended distances, commonly referred to as "airborne" transmission, remain an area of ongoing investigation. Extensive discourse has been dedicated to understanding the dynamics of respiratory droplet transmission and the efficacy of social distancing. Addressing these inquiries is challenging, as it necessitates a comprehensive consideration of factors encompassing momentum transfer, mass exchange with the surrounding air, and the role of evaporation. Furthermore, the interplay between medical and biological factors, such as the infectious dose, alongside engineering variables, requires careful examination. The critical size of larger droplets is contingent upon physical parameters, including ambient air temperature, relative humidity, and velocity. Evaporation plays a crucial role in accurately predicting the dispersion distance of during human respiration [10]. Recommendations for physical distancing should be based on clinical evidence, yet there is limited evidence regarding COVID-19. Additionally, there is controversy surrounding the airborne transmission of COVID-19, close contact, and respiratory droplets as the sole explanation for all infections. Therefore, the purpose of this study was to assess the impact of physical distance on the transmission of COVID-19.

2. Materials and Methods

The methodology employed in this scoping review was adapted from the approach developed by Arksey and O'Malley, along with adherence to the PRISMA reporting guidelines [11, 12]. The framework consisted of five stages:

2.1 Research question formulation

The primary objective of this research was to investigate the impact of physical distance on COVID-19 transmission. Furthermore, the aim was to synthesize the findings and identify areas of research gaps and limitations for future investigations.

2.2 Identification of relevant studies

A comprehensive and systematic literature search was conducted to identify relevant articles. The research encompassed all published articles available in Pub Med and Web of Science databases until May 2022. The search terms used were "COVID-19" OR "SARS-CoV-2" OR "MERS" OR "SARS" AND "Physical Distance" AND "Transmission" without any geographical restrictions. Additionally, we conducted searches on Google Scholar and reviewed the reference lists of the identified articles to locate additional relevant studies. The articles retrieved from the searches conducted using the specified keywords or MeSH terms were imported into Endnote X9 reference manager software (Clarivate Analytics, Philadelphia, PA, USA). Duplicate records were identified and removed to streamline the subsequent screening process. This process ensured that each article was considered only once during the review.

2.3 Selection of appropriate studies

The criteria for data inclusion in the analysis involved: 1- the pathway of COVID-19 transmission, 2- eliminating duplicate studies, and 3- the aspect of physical distance [13]. Nevertheless, we omitted non-peer-reviewed materials (such as letters, editorials, reviews, commentaries, and grey literature) and studies that did not specifically address the COVID-19 transition. Each article's eligibility, based on the title and abstract screening, was independently assessed by two reviewers against the aforementioned criteria. Once irrelevant articles were eliminated, the complete texts of the remaining records were carefully examined to confirm that the initially selected papers addressed the research objectives. In case of any potential conflicts, a third reviewer was consulted, and through discussion, a consensus on whether to include or exclude the articles was reached.

2.4 Data extraction and organization

After finalizing the selection of articles for inclusion, two reviewers independently used Excel spreadsheets to extract and organize relevant data. The following information was extracted from each selected article: title, author, year, location, COVID-19/SARS/MERS, and distance.

2.5 Presentation of findings

Microsoft Excel was utilized to create appropriate charts summarizing the impact of physical distance on COVID-19 transmission, aiming to identify research gaps for future studies. The detailed process of article selection is visualized in Figure 1.

2.6 Production and dispersion of droplets in the air

The process of virus transmission through coughing, sneezing, or talking, is complex and involves various specific disciplines. which is the exhalation Atmospheric sciences, aerosol physics, mechanics, thermodynamics, fluid mechanics, and biochemistry all contribute to understanding this process accurately. While it is challenging to calculate the physical aspects with precision, the general process, etc. makes it difficult to calculate physically accurately. The process can be summarized as follows: During a cough, a turbulent flow expels approximately 2 L of air from the mouth at a velocity of 42 km per hour (or 14 km per hour during speech) [14]. Physical studies have shown that this forceful expulsion creates a turbulent flow that can extend over 2 m before reaching dynamic equilibrium. The expelled air contains numerous droplets of saliva and/or pulmonary secretions, ranging in diameter from fractions of a micrometer to a fraction of a centimeter. These droplets consist of water, glycoproteins, salts, various organic compounds, and potentially a multitude of viruses [15]. Following the expulsion, the droplets undergo complex interactions with the surrounding ambient air [16].

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Depending on the composition and humidity of the environment, these droplets can either evaporate or absorb water from the surroundings. It has been observed that environments with relative humidity above 60% tend to facilitate droplet absorption rather than water evaporation [17], thereby potentially prolonging the survival of viruses within droplets in high-humidity areas. Epidemiological studies have revealed a weak relationship between high ambient temperatures and reduced transmissibility of viruses. On the other hand, higher humidity levels appear to be associated with increased epidemic developments. The transmission of viruses can occur through three primary scenarios. Firstly, direct transmission can transpire when droplets are directly transmitted from one individual to another. Secondly, droplets can settle on surfaces such as the ground, furniture, or objects, leading to transmission via manual contact, facilitated by the force of gravity. Lastly, smaller droplets can undergo evaporation, causing them to shrink and form droplet nuclei. These tiny nuclei, suspended in the air for extended periods ranging from hours to days, may contain water, salts, organic compounds, and viral particles [18]. It is worth noting that even stringent containment measures have not proven entirely effective in limiting the spread of respiratory diseases such as COVID-19. This observation suggests that the use of arbitrary droplet size thresholds may not accurately reflect the dynamics of respiratory emissions, potentially undermining the efficacy of certain preventive measures [19].

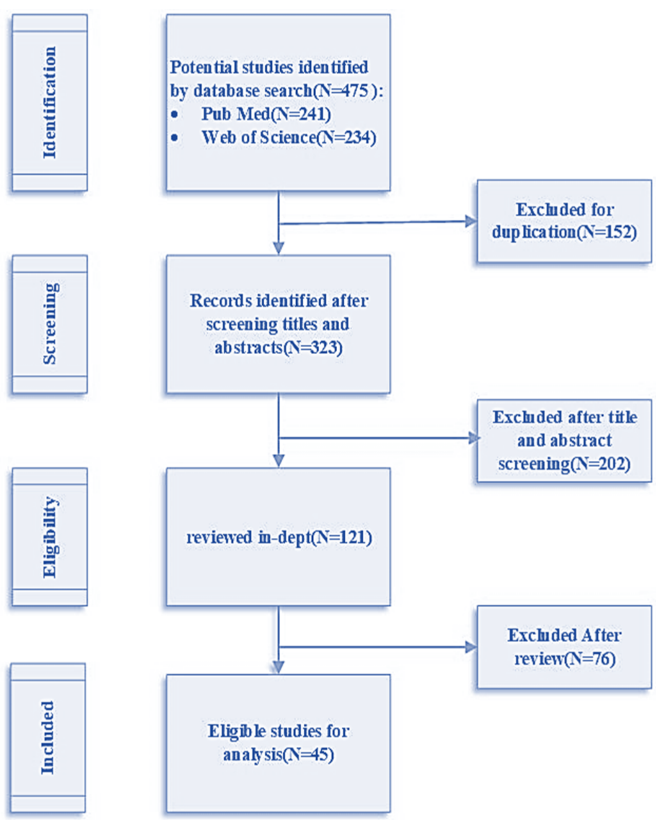

Figure 1. The diagram of eligible studies (inclusive articles) selection

2.7 Respiratory Emissions

Recent studies have shown that exhalation, sneezing, and coughing consist of mucus droplets and a multi-phase (fluffy) gas turbulent cloud that interacts with the surrounding environment by drawing in ambient air and trapping it [20, 21]. Within this turbulent gas cloud, there exists a localized warm and humid atmosphere that allows for a prolonged existence of the droplets, as they are shielded from evaporation. Consequently, the lifespan of these droplets can be significantly extended, ranging from a fraction of a second to several minutes. Furthermore, the forward momentum of the turbulent cloud enables droplets carrying pathogens to be transported to greater distances compared to their dispersion as isolated entities unaccompanied by the presence of a turbulent fluffy cloud. The displacement of these pathogen-laden droplets is contingent upon various physiological and environmental factors unique to each individual, including humidity and temperature. Consequently, the combined effect of the gaseous medium and its cargo of pathogen droplets, irrespective of their size, can facilitate movement spanning a range of 23 to 27 feet (7-8 meters) [21, 22]. Across the path, droplets of different sizes are dispersed at speeds that depend on the degree of turbulence and velocity of the gas cloud, along with the characteristics of the environment (temperature, humidity, etc. airflow). The droplets that settle on surfaces along their trajectory result in surface contamination, while the remaining droplets form a cohesive cluster within a moving cloud. Eventually, the cloud and its droplets come to a halt, and the residual droplets within the cloud can undergo evaporation, giving rise to particles or nuclei that linger in the air for extended periods. The process of evaporation for droplets containing pathogens in biological fluids is intricate. The extent and speed of evaporation are influenced by two primary factors: the temperature and humidity of the environment. Additionally, the internal dynamics of the turbulent cloud, along with the composition of the fluid exhaled by the individual, contribute to the evaporation process.

2.8 Prevention and Precaution

To this day, no biophysical studies specifically addressing droplets and gas cloud formation have been performed in individuals infected with the SARS-CoV-2 virus. However, certain attributes about expiratory gas and respiratory transmission can be applied to this particular pathogen. Consequently, the existing guidelines aimed at mitigating the risk of disease transmission are expected to be efficacious in this context. The World Health Organization (WHO) strongly recommends the importance of maintaining a minimum physical of 3 feet (1 m) between healthcare personnel and other staff as a preventive measure to reduce the transmission of COVID-19 [19]. Maintaining a safe distance from individuals exhibiting symptoms of illness, such as coughing and sneezing is crucial. The Centers for Disease Control and Prevention (CDC) recommends a

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distance of 6 feet (2 meters) to effectively minimize disease transmission [23]. However, the recommended distances provided by the CDC and WHO are established based on estimations that do not explicitly consider the potential presence of high-momentum clouds capable of carrying droplets over long distances. Therefore, healthcare workers need to wear appropriate personal protective equipment, even if they are positioned more than 6 feet away from an infected patient, in order to minimize the risk of infection. The dynamics of turbulent gas clouds can impact the design and usage recommendations for surgical masks and other types of masks. These masks serve the dual purpose of source control, reducing the spread of infection from an infected individual, as well as protecting the wearer from potential transmission by preventing exposure to respiratory droplets from healthy individuals. The effectiveness of N95 masks in providing protection is primarily assessed based on their capacity to filter incoming air and capture aerosol droplets at their core. However, it is important to note that these masks are designed for specific environmental and local conditions and have a limited duration of use. When used as a source control measure, the efficiency of the mask depends on two key factors: its ability to trap particles and its impact on the emission of the gas cloud. The peak expiratory velocity during exhalation can reach approximately 33 to 100 feet per second (10-30 meters per second), resulting in the formation of a cloud that extends to an approximate distance of 23 to 27 feet (7-8 meters). PPE, including masks and other protective gear, plays a crucial role in mitigating the potential risks associated with high-momentum multi-phase turbulent gas clouds that may be expelled during sneezing, coughing, or exposure. However, it is important to note that the surgical masks and N95 respirators currently available for individual use may not be specifically designed to address the complex respiratory release properties of such clouds. A comprehensive understanding of the biophysics involved in the transmission of respiratory diseases from one host to another is essential for comprehending the physiology, pathogenesis, and epidemiological dynamics of disease spread within a population. Gaining insights into the transmission routes, the influence of patient physiology, and implementing effective resource management strategies can significantly enhance the protection of frontline workers and prevent the dissemination of COVID-19 to the most vulnerable members of society. The rapid spread of the coronavirus pandemic has prompted intensified research efforts to better comprehend the transmission dynamics of respiratory diseases and develop optimal measures for disease control [19]. Some relevant studies are summarized in Table 1.

Table 1. Summary of researchers′ studies related to the influence of physical distance on COVID-19 transmission

Author	Year	Country	COVID-19/SARS/MERS	Distance	References
Olsen HJ	2003	China	SARS	1.5m	[24]
Wong TW	2004	China	SARS	2m	[25]
Loeb M	2004	Canada	SARS	2m	[26]
Teleman MD	2004	Singapore	SARS	1m	[27]
Yu IT	2005	China	SARS	2m	[28]
Reynolds M	2006	Vietnam	SARS	1m	[29]
Rea E	2007	Canada	SARS	1m	[30]
Chen W	2009	China	SARS	1m	[31]
Wiboonchutikul S	2016	Thailand	MERS	1m	[32]
Park JY	2016	South Korea	MERS	2m	[33]
Ki HK	2019	South Korea	MERS	2m	[34]
Feiz Aref M	2020	Iran	COVID-19	1.5m	[35]
Cheng HY	2020	Taiwan	COVID-19	1m	[36]
Heinzerling A	2020	USA	COVID-19	1.8m	[37]
Burke RM	2020	USA	COVID-19	2m	[38]
Liu Z	2020	China	COVID-19	1m	[39]
Chanjuan S	2020	USA&China	COVID-19	1.6-3m	[10]
Balachandar S	2020	USA	COVID-19	1-2m	[40]
Jones NR	2020	UK	COVID-19	1m	[41]
Bourouiba L	2020	Cambridge	COVID-19	1m	[19]
EunHwang S	2020	South Korea	COVID-19	2m	[42]
Zhao T	2020	USA&China	COVID-19	1-2m	[43]
Tabatabaeizadeh S-A	2021	Iran	COVID-19	1m	[44]
Mahase E	2021	Cambridge	COVID-19	1m	[45]
BergP	2021	USA	COVID-19	1-2m	[46]
Dewi T	2022	Indonesia	COVID-19	1m	[۴۷]
Bartolucci A	2022	Netherlands	COVID-19	1-2m	[۴۸]

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Social distancing is identified as one of the most crucial factors contributing to the spread of COVID-19. For regular social activities like breathing and talking, the recommended minimum safe distance is 1.5 meters, while the maximum distance for transmission is found to be 8.5 meters. These findings emphasize the importance of maintaining a considerable distance for an extended duration to minimize the risk of COVID-19 infection. Studies have indicated that the COVID-19 virus can be highly contagious through airborne transmission [49]. Respiratory droplets released during exhalation can evaporate and form tiny droplet nuclei that can remain suspended in the air for a significant duration. If these nuclei carry the virus, they can pose a threat to vulnerable populations. Many researchers have suggested social distancing measures based on the transmission of exhaled droplets [50]. Previous studies recommended a minimum distance of 1 m (3 feet) for public activities as a preventive measure against the transmission of the virus through larger droplets. However, subsequent research has revealed that a 1-meter distance alone is insufficient to effectively control the spread of the infection. Further investigations have demonstrated that a safe distance for reducing transmission risk ranges from 2 to 6 m. This expanded range takes into account the behavior of droplets larger than 0.1 mm, which can undergo either evaporation or settle within a 2-meter vicinity, depending on factors such as their size, air humidity, and temperature [51]. The COVID-19 pandemic has spurred scientific investigations that have yielded reports suggesting that respiratory droplets carrying the SARS-CoV-2 virus can travel significant distances of up to eight meters (approximately 23 to 27 feet) when expelled through sneezing. This finding emphasizes that even small droplets possess the capability to traverse across a room, underscoring the potential for airborne transmission. The primary objective of the present study was to establish a correlation between the distance of transmission and the probability of COVID-19 exposure, thereby shedding light on the risks associated with the spread of the virus through droplets of varying sizes. The study findings reaffirm the effectiveness of social distancing as a crucial measure in reducing the risks of COVID-19 infection. They underscore the significance of maintaining an appropriate social distance to effectively prevent cross-infection of the virus. By adhering to recommended distancing guidelines, individuals can significantly mitigate the risk of exposure to respiratory droplets carrying the virus and contribute to the overall containment of COVID-19 transmission.

3. Results and Discussion

This scoping review article focuses on the impact of physical distance on the transmission of COVID-19. It provides a comprehensive overview of the available evidence and highlights key findings related to the production and dispersion of droplets in the air, respiratory emissions, and prevention and precautionary measures. The production and dispersion of droplets in the air are complex processes involving various disciplines such as atmospheric sciences, aerosol physics, mechanics, thermodynamics, fluid mechanics, and biochemistry. In their analysis, Xia *et al.* showed that longer trip lengths, certain age groups, and particular travel sites all had a greater effect on mobility decrease on COVID-19 transmission [52]. The social distancing regulations of 6 feet may not be adequate to guard against inter-person aerosol transfer, according to a study by Feng *et al.* (2020), and a larger distance should be taken into consideration [53]. Wearing masks and maintaining physical distance is particularly efficient at halting the transmission of COVID-19, as shown by Widyawardani *et al.* (2022) [54]. A nonlinear dose-response association between temperature and COVID-19 transmission was found in a different investigation by Zhang *et al.* (2020), and air pollution indicators were favorably connected with newly reported confirmed cases [55]. In order to reduce exposure to respiratory droplets during sneezing, Chu *et al.* (2020) showed that physical separation of more than one meter is effective [56], however, Chea (2021) claimed that a distance of 2.8 m or larger is more effective. Also helpful in lowering the risk of infection are face masks and eye protection [57]. According to Setti *et al.* (2020), face masks are required for adequate protection, and the recommended inter-personal distance of 2 meters may not be sufficient to avoid airborne transmission [58]. Additionally, Tanis *et al.'s* prior work involved a significant behavioral trial and discovered that avoiding close contact and using masks are effective ways to stop the spread of COVID-19 [59]. The study conducted by Praharaj *et al.* (2020) found a significant correlation between mobility to groceries and retail stores and the incidence of COVID-19 in India [60]. While Shafaghi *et al.* (2020) proposed that the conventional methods employed to protect the public from bio attacks may not be suitable for COVID-19. The study highlighted the differences in droplet generation between COVID-19 and typical influenza viruses, suggesting that the transmission dynamics of COVID-19 differ from those of conventional influenza viruses. The findings of this study emphasized the need for tailored approaches and preventive measures specifically designed for the unique characteristics of COVID-19 to effectively mitigate its transmission [61]. In a follow-up study Hu *et al.* (2021) found that the number of new COVID-19 infections correlated strongly with individuals sitting close to one another for long periods without interruption [62]. The researchers concluded that in the US sample, there was a significant relationship between the intention to maintain distance and avoid going out, and actual behavior [63]. Zeng *et al.* (2021) conducted a study that revealed a positive association between population mobility and daily COVID-19 incidence at both the state level and within the top five counties in South Carolina [64]. The report further stated that maintaining a physical distancing of at least 1 m is associated with a significant reduction in COVID-19 infection rates. Moreover, it suggested that keeping a distance of 2 m between individuals may potentially yield even greater effectiveness in preventing the transmission of the virus [65]. The article highlights that during coughing or speaking, droplets are forcefully expelled from the mouth, creating a turbulent flow that can spread more than 2 m in ambient air [16, 17]. The droplets expelled during these actions contain water vapor, saliva, secretions, and potentially thousands of viruses. Environmental factors, including humidity, temperature, and air composition, play a significant role in the evaporation of respiratory droplets. Higher humidity levels can lead to longer droplet survival, suggesting that the virus may persist longer in humid environments. The transmission of the virus can occur through direct contact, contact with contaminated surfaces, or through smaller droplets that evaporate and form airborne droplet nuclei. The section also discusses respiratory emissions and the formation of gas clouds. The article emphasizes the importance of prevention and precautionary measures to minimize COVID-19 transmission [21, 22]. Current recommendations from WHO and CDC include maintaining physical distance, avoiding close contact with symptomatic individuals, and wearing masks [19, 23]. However, the article raises concerns about the recommended distances, as they do not account for the presence of high-momentum clouds that can carry droplets over longer distances. It also highlights the limitations of surgical masks and N95 masks in controlling the emission of respiratory droplets [49-51]. The effectiveness of these masks depends on their ability to trap particles and their impact on gas cloud emission. To support the discussion, the article provides a summary of relevant studies that have examined the influence of physical distance on COVID-19 transmission. The studies listed in Table 1 include research conducted during the SARS and MERS outbreaks, as well as studies specifically focusing on COVID-19. The findings from these studies vary in terms of the recommended safe distances, with some suggesting a minimum distance of 1 meter and others recommending distances ranging from 2 to 6 m. It is highlighted that droplets carrying the virus can travel beyond 6 m when forcefully expelled during coughing or sneezing.

3.1 Limitations

Our study has several limitations. Firstly, most of the studies we included in our review were observational and not randomized; many of them did not fully adjust for relevant variables or potential confounders. Additionally, a number of these studies had a considerable risk of bias due to the high prevalence of non-differential missing data or reporting bias, and substantial heterogeneity was noted between study characteristics, populations, interventions, and study designs, however, the review appraisal currently of the best available evidence could be used to inform.

4. Conclusion

In conclusion, SARS-CoV-2 has emerged as a substantial threat to respiratory health, leading to various respiratory disorders and, in severe cases, fatalities. The transmission of the virus occurs rapidly through direct contact with infected individuals or contaminated objects. To effectively mitigate the transmission of the virus, the implementation of physical distancing measures is strongly recommended by national and international health institutions. These measures entail avoiding crowded places and maintaining a safe distance from individuals displaying symptoms of illness. However, comprehending the intricate dynamics of respiratory droplets and their role in virus transmission is a complex endeavor that necessitates the collaboration of multiple scientific disciplines. The fields of atmospheric sciences, fluid mechanics, biochemistry, and more are all involved in deciphering the mechanisms behind droplet formation, dispersion, and subsequent transmission. By combining knowledge from diverse scientific domains, researchers can gain a deeper understanding of the transmission dynamics of respiratory viruses and develop informed strategies for prevention and control. Various factors, including temperature, humidity, velocity, and evaporation, play key roles in the survival and spread of the virus. Despite ongoing debates about the exact mechanisms of transmission, physical distancing has been proven effective in reducing the spread of COVID-19. The collection of data and studies conducted in this field provide valuable insights into the impact of physical distance on COVID-19 transmission. To ensure personnel protection, it has been observed that a minimum distance of 1 m is necessary, although a distance of up to 2 m might be more effective in reducing the risk of transmission. It is crucial that recommendations for maintaining appropriate distances and the use of personal protective equipment are based on clinical evidence and ongoing research. By continuously monitoring and analyzing data, healthcare authorities can provide up-to-date guidelines that prioritize the safety of individuals and the prevention of further virus transmission.

Authors' Contributions

Abdolkazem Neisi, Nastaran Talepour: Conceptualization; methodology; validation; formal analysis; investigation; resources; supervision. Majid Farhadi: Writing-review & editing; supervision.

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Conflicts of Interest

The authors declare that they have no conflict of interests.

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Ethical considerations

The authors declare that they have no ethical issues.

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References

1. Bao L, Deng W, Huang B, Gao H, Liu J, Ren L, et al. The Pathogenicity of SARS-CoV-2 in hACE2 Transgenic Mice. *Nat.* 2020; 583(7818): 830-3.

2. Shereen MA, Khan S, Kazmi A, Bashir N, Siddique R. COVID-19 Infection: Origin, Transmission, and Characteristics of Human Coronaviruses. *J Adv Res.* 2020; 24: 91-8.

3. Jin Y, Yang H, Ji W, Wu W, Chen S, Zhang W, et al. Virology, Epidemiology, Pathogenesis, and Control of COVID-19. *Viruses.* 2020; 12(4): 372.

4. Roosa K, Lee Y, Luo R, Kirpich A, Rothenberg R, Hyman J, et al. Real-Time Forecasts of the COVID-19 Epidemic in China from February 5th to February 24th, 2020. *Infect Dis Model.* 2020; 5: 256-63.

5. Zareh Gavgani V. Infodemic in the Global Coronavirus Crisis. *Depiction Health.* 2020; 11(1): 1-5.

6. Dalton C, Corbett S, Katelaris A. Pre-emptive Low Cost Social Distancing and Enhanced Hygiene Implemented Before Local COVID-19 Transmission Could Decrease the Number and Severity of Cases. *Med J Aust.* 2020; 212(10): 1.

7. Ross SE, Niebling BC, Heckert TM. Sources of Stress Among College Students. *Coll Stud J.* 1999; 33(2): 312.

8. Pfattheicher S, Nockur L, Böhm R, Sassenrath C, Petersen MB. The Emotional Path to Action: Empathy Promotes Physical Distancing and Wearing of Face Masks During the COVID-19 Pandemic. *Psychol Sci.* 2020; 31(11): 1363-73.

9. Xiao C. A Novel Approach of Consultation on 2019 Novel Coronavirus (COVID-19)-Related Psychological and Mental Problems: Structured Letter Therapy. *Psychiatry Investig.* 2020; 17(2): 175.

10. Sun C, Zhai Z. The Efficacy of Social Distance and Ventilation Effectiveness in Preventing COVID-19 Transmission. *Sustain Cities Soc.* 2020; 62: 102390.

11. Arksey H, O'Malley L. Scoping Studies: Towards a Methodological Framework. *Int J Soc Res Methodol.* 2005; 8(1): 19-32.

12. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *Int J Surg.* 2021; 88: 105906.

13. Amrithaa B, Rani SL, Geetha RV. Preventive Measures Against Covid in Public Places. *Int J Curr Res Rev.* 2020; 79-85.

14. Shao S, Zhou D, He R, Li J, Zou S, Mallery K, et al. Risk Assessment of Airborne Transmission of COVID-19 by Asymptomatic Individuals Under Different Practical Settings. *J Aerosol Sci.* 2021; 151: 105661.

15. Nicas M, Nazaroff WW, Hubbard A. Toward Understanding the Risk of Secondary Airborne Infection: Emission of Respirable Pathogens. *J Occup Environ Hyg.* 2005; 2(3): 143-54.

16. Wallace JM, Hobbs PV. Atmospheric Science: An Introductory Survey. *Elsevier.* 2006.

17. Marr LC, Tang JW, Van Mullekom J, Lakdawala SS. Mechanistic Insights into the Effect of Humidity on Airborne Influenza Virus Survival, Transmission and Incidence. *J R Soc Interface.* 2019; 16(150): 20180298.

18. Crema E. Not Even the Air of Empty Spaces is Coronavirus Free (Two Meters is Not a Safe Distance). *Arxiv Preprint Arxiv: 200608823.* 2020.

19. Bourouiba L. Turbulent Gas Clouds and Respiratory Pathogen Emissions: Potential Implications for Reducing Transmission of COVID-19. *Jama.* 2020; 323(18): 1837-8.

20. Scharfman B, Techet A, Bush J, Bourouiba L. Visualization of Sneeze Ejecta: Steps of Fluid Fragmentation Leading to Respiratory Droplets. *Exp Fluids.* 2016; 57(2): 1-9.

21. Bourouiba L, Dehandschoewercker E, Bush JW. Violent Expiratory Events: On Coughing and Sneezing. *J Fluid Mech.* 2014; 745: 537-63.

22. Bourouiba L. A Sneeze. *N Engl J Med.* 2016; 375(8): e15.

23. Centers for Disease Control and Prevention (CDC). Travelers from Countries with Widespread Sustained (Ongoing) Transmission Arriving in the United States. 2020. Available from: https://www. cdc. gov/coronavirus/2019-ncov/travelers/after-travel-precautions. html.

24. Olsen SJ, Chang HL, Cheung TY, Tang AF, Fisk TL, Ooi SP, et al. Transmission of the Severe Acute Respiratory Syndrome on Aircraft. *N Engl J Med.* 2003; 349(25): 2416-22.

25. Wong TW, Lee CK, Tam W, Lau JT, Yu TS, Lui SF, et al. Cluster of SARS among Medical Students Exposed to Single Patient, Hong Kong. *Emerg Infect Dis.* 2004; 10(2): 269.

26. Loeb M, McGeer A, Henry B, Ofner M, Rose D, Hlywka T, et al. SARS among Critical Care Nurses, Toronto. *Emerg Infect Dis.* 2004; 10(2): 251.

27. Teleman MD, Boudville I, Heng B, Zhu D, Leo Y. Factors Associated with Transmission of Severe Acute Respiratory Syndrome among Health-Care Workers in Singapore. *Epidemiol Infect.* 2004; 132(5): 797-803.

28. Yu IT, Wong TW, Chiu YL, Lee N, Li Y. Temporal-spatial Analysis of Severe Acute Respiratory Syndrome among Hospital Inpatients. *Clin Infect Dis.* 2005; 40(9): 1237-43.

29. Reynolds MG, Anh BH, Thu VH, Montgomery JM, Bausch DG, Shah JJ, et al. Factors Associated with Nosocomial SARS-CoV Transmission among Healthcare Workers in Hanoi, Vietnam, 2003. *BMC Public Health.* 2006; 6(1): 1-9.

30. Rea E, Lafleche J, Stalker S, Guarda B, Shapiro H, Johnson I, et al. Duration and Distance of Exposure are Important Predictors of Transmission among Community Contacts of Ontario SARS Cases. *Epidemiol Infect.* 2007; 135(6): 914-21.

31. Chen WQ, Ling WH, Lu CY, Hao YT, Lin ZN, Ling L, et al. Which Preventive Measures Might Protect Health Care Workers from SARS?. *BMC Public Health.* 2009; 9: 1-8.

32. Wiboonchutikul S, Manosuthi W, Likanonsakul S, Sangsajja C, Kongsanan P, Nitiyanontakij R, et al. Lack of Transmission among Healthcare Workers in Contact with a Case of Middle East Respiratory Syndrome Coronavirus Infection in Thailand. *Antimicrob Resist Infect Control.* 2016; 5(1): 1-5.

33. Park JY, Kim BJ, Chung KH, Hwang YI. Factors Associated with Transmission of Middle East Respiratory Syndrome among Korean Healthcare Workers: Infection Control Via Extended Healthcare Contact Management in a Secondary Outbreak Hospital. *Respirol.* 2016; 21(suppl 3): 89.

34. Ki HK, Han SK, Son JS, Park SO. Risk of Transmission Via Medical Employees and Importance of Routine Infection-Prevention Policy in a Nosocomial Outbreak of Middle East Respiratory Syndrome (MERS): A Descriptive Analysis from a Tertiary Care Hospital in South Korea. *BMC Pulm Med.* 2019; 19(1): 1-12.

35. Arefi MF, Poursadeqiyan M. A Review of Studies on the Epidemic Crisis of COVID-19 Disease with a Preventive Approach. *Work.* 2020; 66(4): 717-29.

36. Cheng HY, Jian SW, Liu DP, Ng TC, Huang WT, Lin HH. High Transmissibility of COVID-19 Near Symptom Onset. *MedRxiv.* 2020; 2020-03.

37. Heinzerling A, Stuckey MJ, Scheuer T, Xu K, Perkins KM, Resseger H, et al. Transmission of COVID-19 to Health Care Personnel During Exposures to a Hospitalized Patient-Solano County, California, February 2020. *Morb Mortal Wkly Rep.* 2020; 69(15): 472.

38. Burke RM, Balter S, Barnes E, Barry V, Bartlett K, Beer KD, et al. Enhanced Contact Investigations for Nine Early Travel-Related Cases of SARS-CoV-2 in the United States. *PloS One.* 2020; 15(9): e0238342.

39. Liu Z, Ye Y, Zhang H, Guohong X, Yang J, Wang J. Analysis of the Spatio-Temporal Characteristics and Transmission Path of COVID-19 Cluster Cases in Zhuhai. *Trop Geogr.* 2020.

40. Balachandar S, Zaleski S, Soldati A, Ahmadi G, Bourouiba L. Host-to-host Airborne Transmission as a Multiphase Flow Problem for Science-Based Social Distance Guidelines. *Elsevier.* 2020; 132: 103439.

41. Jones NR, Qureshi ZU, Temple RJ, Larwood JP, Greenhalgh T, Bourouiba L. Two Metres or One: What is the Evidence for Physical Distancing in Covid-19?. *BMJ.* 2020; 370.

42. Hwang SE, Chang JH, Oh B, Heo J. Possible Aerosol Transmission of COVID-19 Associated with an Outbreak in an Apartment in Seoul, South Korea, 2020. *Int J Infect Dis.* 2021; 104: 73-6.

43. Zhao T, Cheng C, Liu H, Sun C. Is One-Or Two-Meters Social Distancing Enough for COVID-19? Evidence for Reassessing. *Public Health.* 2020; 185: 87.

44. Tabatabaeizadeh SA. Airborne Transmission of COVID-19 and the Role of Face Mask to Prevent It: A Systematic Review and Meta-Analysis. *Eur J Biomed Res.* 2021; 26(1): 1-6.

45. Mahase E. Covid-19: Physical Distancing of at Least One Metre is Linked to Large Reduction in Infection. *BMJ Br Med J.* 2020; 369.

46. Van Den Berg P, Schechter-Perkins EM, Jack RS, Epshtein I, Nelson R, Oster E, et al. Effectiveness of 3 Versus 6 Ft of Physical Distancing for Controlling Spread of Coronavirus Disease 2019 among Primary and Secondary Students and Staff: A Retrospective, Statewide Cohort Study. *Clin Infect Dis.* 2021; 73(10): 1871-8.

47. Dewi TK, Savitri DA, Sudirman MA, Rohmatullaili RA, Rahmadianti S, Ardi R. Survey Data of Determinants Related to Covid-19 Preventive Behaviors During the Second Waves in Indonesia Using the Reasoned Action Approach. *Data Brief.* 2022; 42: 108147.

48. Bartolucci A, Templeton A, Bernardini G. How Distant? An Experimental Analysis of Students′ COVID-19 Exposure and Physical Distancing in University Buildings. *Int J Disaster Risk Reduct.* 2022; 70: 102752.

49. Morawska L, Cao J. Airborne Transmission of SARS-CoV-2: The World Should Face the Reality. *Environ Int.* 2020; 139: 105730.

50. Organization WH. Infection Prevention and Control of Epidemic-and Pandemic-prone Acute Respiratory Infections in Health Care. *WHO.* 2014.

51. Xie X, Li Y, Chwang A, Ho P, Seto W. How far Droplets Can Move in Indoor Environments-revisiting the Wells Evaporation-falling Curve. *Indoor Air.* 2007; 17(3): 211-25.

52. Xia J, Yin K, Yue Y, Li Q, Wang X, Hu D, et al. Impact of Human Mobility on COVID-19 Transmission According to Mobility Distance, Location, and Demographic Factors in the Greater Bay Area of China: Population-Based Study. *JMIR Public Health Surveill.* 2023; 9(1): e39588.

53. Feng Y, Marchal T, Sperry T, Yi H. Influence of Wind and Relative Humidity on the Social Distancing Effectiveness to Prevent COVID-19 Airborne Transmission: A Numerical Study. *J Aerosol Sci.* 2020; 147: 105585.

54. Widyawardani TN, Pamungkasari EP, Murti B. The Effectiveness of Wearing Mask and Physical Distancing in Preventing the COVID-19 Transmission. *J Epidemiol Public Health.* 2022; 7(3): 355-66.

55. Zhang Z, Xue T, Jin X. Effects of Meteorological Conditions and Air Pollution on COVID-19 Transmission: Evidence from 219 Chinese Cities. *Sci Total Environ.* 2020; 741: 140244.

56. Chu D, Akl E, El-Harakeh A, Bognanni A, Lotfi T, Loeb M, et al. Physical Distancing, Face Masks, and Eye Protection to Prevent Person-Person COVID-19 Transmission: A Systematic Review and Meta-Analysis (Preprint). 2020.

57. Chea B, Bolt A, Agelin-Chaab M, Dincer I. Assessment of Effectiveness of Optimum Physical Distancing Phenomena for COVID-19. *Phys Fluids.* 2021; 33(5).

58. Setti L, Passarini F, De Gennaro G, Barbieri P, Perrone MG, Borelli M, et al. Airborne Transmission Route of COVID-19: Why 2 Meters/6 Feet of Inter-Personal Distance Could not be Enough. *Int J Environ Res Public Health.* 2020; 17(8): 2932.

59. Tanis CC, Leach NM, Geiger SJ, Nauta FH, Dablander F, Van Harreveld F, et al. Smart Distance Lab′s Art Fair, Experimental Data on Social Distancing During the COVID-19 Pandemic. *Sci Data.* 2021; 8(1): 179.

60. Praharaj S, Han H. A Longitudinal Study of the Impact of Human Mobility on the Incidence of COVID-19 in India. *MedRxiv.* 2020; 2020-12.

61. Shafaghi AH, Rokhsar Talabazar F, Koar A, Ghorbani M. On the Effect of the Respiratory Droplet Generation Condition on COVID-19 Transmission. *Fluids.* 2020; 5(3): 113.

62. Hu M, Lin H, Wang J, Xu C, Tatem AJ, Meng B, et al. Risk of Coronavirus Disease 2019 Transmission in Train Passengers: An Epidemiological and Modeling Study. *Clin Infect Dis.* 2021; 72(4): 604-10.

63. Kowalsky JM, Mitchell AM, Okdie BM. Maintaining Distance and Avoiding Going out During the COVID-19 Pandemic: A Longitudinal Examination of an Integrated Social Cognition Model. *Psychol Health.* 2021: 1-22.

64. Zeng C, Zhang J, Li Z, Sun X, Olatosi B, Weissman S, et al. Spatial-temporal Relationship between Population Mobility and COVID-19 Outbreaks in South Carolina: Time Series Forecasting Analysis. *J Med Internet Res.* 2021; 23(4): e27045.

65. Mahase E. Covid-19: Physical Distancing of at Least one Metre is Linked to Large Reduction in Infection. 2020.